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Inequality Aversion Dominates Competitive Behavior in Dynamic Sequential Duopolies

Maik Kecinski

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by Maik Kecinski*

Abstract

This study introduces a two-period sequential choice model, which is tested in controlled laboratory experiments. Players have a one time opportunity to invest positive relative profits to lower marginal cost and gain competitive advantage. Theory predicts one sub-game perfect Nash equilibrium in pure strategies with first movers earning much larger payoffs than second movers. On the contrary, experimental results show that Cournot play is modal. Participants appear to be inequality averse, which was brought on by either a fear of punishment or pure preferences for equal pay.

Keywords

Repeated Games, Laboratory Experiments, Stackelberg Equilibrium, Competitive Advantage, Inequality Aversion, Punishment

JEL Classifications

C73, C91, D03, D43, D69

*Kecinski: University of Alberta, Resource Economics and Environmental Sociology, 505 GSB, Edmonton, AB T6G 2H1, Canada (e-mail: kecinski@ualberta.ca).

1 Introduction

“No one has the right, and few the ability, to lure economists into reading another article on oligopoly theory without some advance indication of its alleged contribution” (Stigler, 1964). A large amount of articles has emerged since Stiegler wrote those lines in 1964 and according to Selten et al. (1997), “After 150 years since Cournot (1838) the duopoly problem is still open.” Since Cournot introduced his equilibrium, research in quantity games has progressed to take on much more of a behavioral character. Assumptions about information and preferences were relaxed allowing for different approaches to develop. Especially since Alchian (1950) the idea that it is only profit maximization that drives firm behavior has been disputed. Many articles sprung from Alchian’s insightful conclusion that firms do not have enough information to be profit maximizers. For example, Schenk-Hoppé (2000) argue that obtaining information about demand and cost functions is either extremely costly or simply impossible, which challenges the game theoretical toolbox; while Harstad and Selten (2013) call for closer collaboration between theoretical modeling and experiments and that too little headway has been made to move away from the optimization approach.

This study introduces a two period dynamic sequential choice duopoly where players compete over market share through their outputs (quantity). A novel aspect of this model is that players can invest positive relative profits into cost-saving technologies to lower marginal cost in future period, thus build competitive advantage and increase market share. Theory predicts large payoff discrepancies between first and second movers, i.e. there exists one sub-game perfect Nash equilibrium in pure strategies, which leaded to ever-increasing market share for first movers. However, evidence from controlled laboratory experiments suggest that theory is a poor predictor – Stackelberg leadership never emerged. Instead, results show that the Cournot quantity is the most frequently chosen quantity with only minor differences in payoffs between first and second movers. Some first movers choose Cournot quantities in an effort to sustain long term relationships with equal market shares, while others learn to play Cournot through punishment by second movers. Overall, investment into cost saving technologies only play a minor role and the driving force is equality in payoffs.

2 Relevant Literature

Alchian (1950) suggested that if firms do not know how to maximize, they may either imitate or attempt trial and error. It is straight forward that if lacking necessary optimization information firms will try to imitate competitors with superior performance. In other words, if positive profits exist, and the market is symmetric, it is relative performance that matters as there is no other reference point against which to measure. The firm with the highest output will outperform its' lower output competitors and, thus, be imitated. Vega-Redondo (1997) Vega-Redondo (1997) shows theoretically that long-run behavior is characterized by the Walrasian quantity, when all firms chose simultaneously, produce the same good, and face a downward sloping demand curve (see also Rhode & Stegeman, 2001). His model, however, only holds true if no firm maintains memory of previous profits, i.e. eliminating any reference point other than relative current performance.

On the other hand, social preferences, such as spite have been shown to render oligopolies more competitive than predicted by theory. For example, if firms are perfectly spiteful markets will converge at the Walrasian equilibrium irrespective of the information available to players. Spiteful players are willing to accept reductions in payoff if, through their behavior, their competitors experience even larger reductions in payoff (see Schaffer, 1989; Hamilton, 1970). Smith & Price (1973) showed that spiteful behavior is an evolutionary stable strategy, in that, if adopted by most players, there exist no other strategy that would result in higher market "fitness." Vriend (2000) suggested that there are two aspects to spite: one being pure spite, where players receive enjoyment from beating others; and two, spiteful behavior relating to the limited perception of players (bounded rationality, learning, information etc).

Experimental evidence from simultaneous choice games have provided insights into the behaviors. Selten et al. (1997) showed that in a finite super game of asymmetric Cournot duopoly, instead of optimization, players use fairness to form cooperative goals called ideal points, which they try to achieve through reciprocation. For example, Selten & Ostmann (2000) provide evidence that symmetric duopolies with common knowledge of demand and cost function, as well as communication, seem to have a tendency towards collusive behavior, while asymmetric duopolies without communication and with little information about other players' profits have the tendency to converge towards the Cournot-Nash equilibrium. Huck et al. (1999) generalize these findings and suggested that, in general, more information about the market yields less competitive outcomes while more information about competitors yields more competitive outcomes (see also Huck et al., 2000). Furthermore, behavior in these games will depend on the time horizon, which allows players to learn use newly available information. Two learning dynamics can be distinguished, (1) learning by imitation of others and (2) learning by introspection, where introspective learning leads to the Nash equilibrium and imitative leaning leads to the Walrasian outcome (see also Riechmann, 2006b,a; Bergin & Bernhardt, 2009).

Considerably less experimental work has been done on behaviors in sequential choice games. Huck et al. (2001), for example, studied a Stackelberg duopoly experimentally and found considerable differences between theorized and observed behavior. When pairs were fixed, markets became less competitive, i.e. Stackelberg leaders produced less output than predicted by theory, while Stackelberg followers produced more than predicted by theory – the authors argue that this behavior is in line with prediction by Fehr & Schmidt (1999), as the behavior of the Stackelberg follower can be explained by reward for cooperative behavior and punishment for choosing an exploitative approach. Huck et al. (2002) Huck et al. (2002) showed experimentally that despite theoretical predictions Stackelberg leadership almost never emerged (see also Muller, 2006); instead, they found that the Cournot-Nash was achieved about 50% of the time. Fonseca et al. (2005) added asymmetry to the sequential choice model which, theoretically, should strengthen Stackelberg leadership of the low-cost firm. However, experimental evidence suggests that despite the introduced asymmetry no significant differences, compared to the symmetric case, can be observed and Cournot play is the most frequently played quantity.

The model presented in this study adds to this literature by introducing a dynamic two-period model where players can build competitive advantage by outperforming their competition in period one. To the best of the author's knowledge no other experiment has tested this model before.

3 Theoretical Predictions

The following experimental model is a simple parameterized oligopoly with 2-periods. There exists a one-time possibility (period one) to lower marginal cost if players successfully outperform their competitor in terms of profit, i.e. positive relative profit. The idea goes as follows, if players achieve the same level of profits, then, by assumption, all players can invest the same amount into cost-saving technologies and lower marginal cost by the same amount. If, however, one player achieves positive relative profit, then, by assumption, that player may gain a competitive advantage in the following period due to the larger investment into cost-saving technologies. Bester & Petrakis (1993), for example, argued that the more substitutable goods are, the larger the amount of investment into cost reduction may be.

Inverse Demand:

$$P^t(Y^t) = 160 - Y^t, \text{ where } Y^t = \sum_{i=1}^{2} y_i^t \tag{1}$$

Firms face the following cost function:

$$C^t(y_i^t) = 40(1 - \delta_i^t)y_i^t, \text{ where} \tag{2}$$

$$\delta_i^t = \frac{I_i^{t-1}}{\pi_i^{t-1}}2, \text{ and} \tag{3}$$

$$I_i^{t-1} = \frac{\pi_i^{t-1} - \pi_{-i}^{t-1}}{2} \forall\ \pi_i^{t-1} > \pi_{-i}^{t-1} > 0, \text{ else } I_i^{t-1} = 0 \tag{4}$$

It follows that:

$$\delta_i^t = \frac{\pi_i^{t-1} - \pi_{-i}^{t-1}}{\pi_i^{t-1}} \tag{5}$$

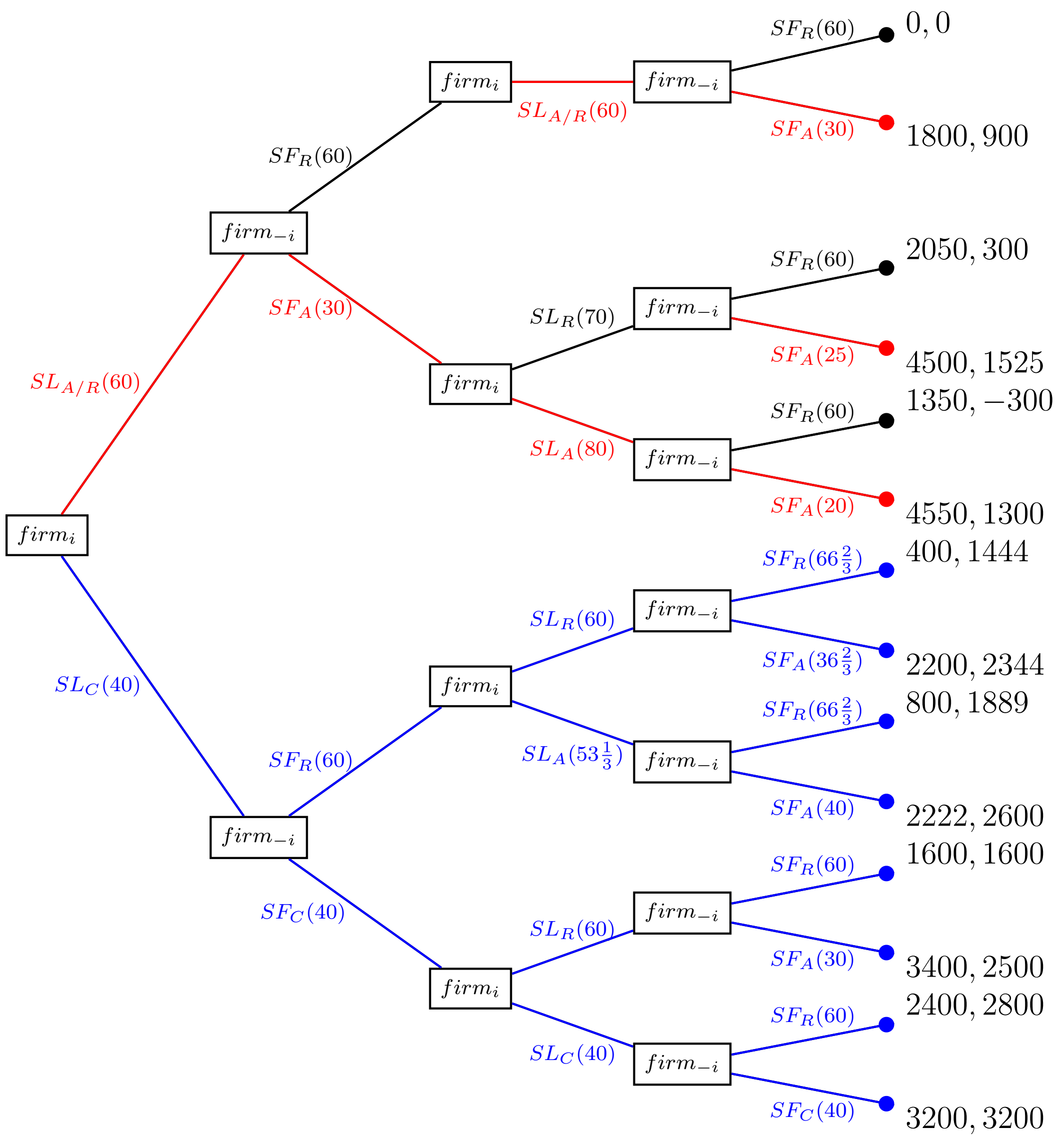
Equation (2) deserve some clarification. It is proposed that in period t cost not only depend on output y_i^t but also on delta δ_i^t. The size of δ_i^t depends on an amount invested I_i^{t-1} into cost-saving technologies in the previous period. The investment is double effective in cost. For simplicity it was predetermined that players would invest half their positive relative profits. Alternatively one might leave the investment up to the player. This, however, renders the experiment much more complicated as the payoff vector for period 2 becomes very large and computation of possible future scenarios would be too complicated, at least for this present experiment (however, it would make for an interesting future experiment). Mathematically speaking, equation (3) and (4) are obsolete. In the experiment, however, it is important for players to understand that any decrease in marginal cost is the result of an investment into cost-saving technologies as opposed to merely a reward for positive relative profits. This also explains the difference between profit and payoff, as a player's profit may not be her payoff due to the money invested. Both firms start out in cost symmetry, as the cost function's δ_i^t does not yet exist, assuming t being the first period.

Due to the dynamic character of the model we limited the number of quantity choices to four. It was essential that player were able to foresee all eventualities to make "informed" decisions, which might have been compromised using more quantities. The available quantities consisted of the absolute profit maximizing quantity (A), the relative profit maximizing quantity (R) and two other quantities, one between A and R referred to as high quantity (H) and one being the lowest quantity (L). H and L were fitted in equal distances between and below A and R. The game tree, Figure 1, summarizes the outcomes and allows for a concise way to find the existing sub-game perfect Nash equilibrium in pure strategies. The equilibrium path is highlighted in red and consists of absolute profit maximizing strategies (A) throughout. This result is perfectly in line with a simpler one-shot Stackelberg game and predicts that the Stackelberg leader (SL) will exploit the Stackelberg follower (SF) using first mover advantage at [(60|30) and (80|20)], though, at substantially higher (lower) profits for the first mover (second mover) due to the arising asymmetry, i.e. the lower marginal cost for the Stackelberg leader in period two. The game tree (Figure 1) only contains the absolute profit maximizing and relative profit maximizing quantity as the other two quantities do not play a role in the equilibrium analysis. Absolute and relative profit maximizing quantities may fall together on the same quantity for the Stackelberg leader, indicated as (A/R). Given previous findings, for example Huck et al. (2001), it may be of interest to include a "equality branch," consisting of the Cournot quantity (C) – denoted as the blue branch in Figure 1. The Cournot branch, in fact, became the most frequently selected branch indicting that payoff equality mattered greatly. The theoretical prediction shows that first movers earn 4550 while second movers only earn 1300. The equal payoff scenario in the Cournot branch gives each player a payoff of 3200, which, aggregated, provides higher markets efficiency as $6400 > 5850$.

4 Experimental Procedures

Experiments were conducted at a research university in the Southwestern part of Germany. Participants were recruited in class and through sign-up list on campus. All participants were either students of business administration, business administration in connection with a multitude of natural science concentration, engineering, or mathematics. Most participants had reached at least their second year of study. The experiments were part pen and paper and part computer based. Participants All quantities were selected from computer spreadsheets and entered (handwritten) into provided report cards. Subjects were randomly assigned to a specific computer in the laboratory, which ensured the initial random matching of participants. Whether players were Stackelberg leaders or followers was revealed to them at their respective computers. After the instructions were read and the spreadsheet thoroughly explained, participants were encouraged to ask questions, which were carefully answered – without providing information that went beyond the general instructions. Participants were asked to fill out a short quiz to verify that everyone had understood the instructions and experiment – they had. The experiment consisted of ten games of 2 periods each, which

Figure 1: Stackelberg game with addition of Cournot branch



Note: A is the absolute profit maximizing quantity, R the relative profit maximizing quantity, L and H are low and high quantities placed in equal distances around A and R. SL denotes the Stackelberg Leader, who is the first mover and SF denotes the Stackelberg Follower, or second mover.

participants were informed about. Participants could select between at least four[1] quantity options, including the absolute profit maximizing quantity, the relative profit maximizing quantity, a high quantity, and a low quantity (but these quantities were not labeled as such).

Participants were informed that they would receive a time compensation of 7.00 EUR and additionally would receive the amount (payoff) earned in each period of the experiment. Participants were informed that the payment in each period would depend on their quantity choice and the quantity choice of their opponent, who was not known to them and was not visually accessible. Payoffs had a scaling factor of 1000, meaning that an actual payoff to players in the amount of, for example, 1.60 EUR corresponded to the modeled payoff of 1600. Leaders and followers were aware of the sequential nature of the experiment and were called first and second movers. In every period participants would note their quantity choice on the provided report cards, which was completed by adding the opponents quantity and both players payoff after every period. Hence, report cards also served as a history of outcomes as the experiment progressed. Excel spreadsheets served as an information tool for both leaders and followers, i.e. players would simulate all quantity combinations of first and subsequently second period and their respective outcomes. For example, leaders would test how each of their quantities would generate four different quantities for followers. They were then able to make guesses about followers' choices and payoffs in period one, as well as second period quantities and payoffs. Followers were also able simulate all possible outcomes, but had to wait until first movers made their choices before they knew what quantities were actually available for selection. This is straight forward, as different quantities chosen by Stackelberg leader would result in different quantities available to Stackelberg followers due to the sequential 4-quantity setup. This procedure was then repeated for all 10 games or 20 periods. All participants were informed that they are in a market consisting of themselves and one other player. They also knew that they would play the same player in all 10 games. The four different quantity option in period one available to Stackelberg leaders were: 30 (L), 40 (C), 50 (H), and 60 (A/R), each resulting in four different quantities available to followers. Furthermore, participants knew that if they outperformed their competition, they would have an advantage in the following period – specifically, participants knew that the higher their period payoff was above that of their competitor the larger their advantage in the following period.

For Stackelberg leaders, in period one, absolute and relative profit maximizing strategies

[1]Note, depending on period one choices, the relative and absolute profit maximizing quantity may be different in period two. Therefore, there may be five possible quantities in period two.

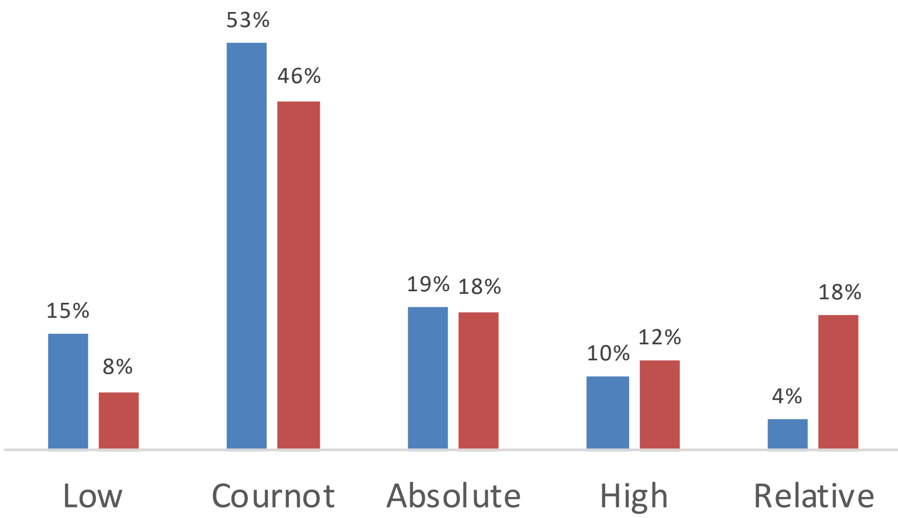
were identical, i.e. 60. The Cournot quantity, 40, was added to give first movers the option to offer a quantity to the second mover that seemed fair in terms of equal payoff – second movers then decided whether they wanted to reciprocate or not. Both players had to consider their future relationship, i.e. responding aggressively to a Cournot quantity may destroy future cooperation. Hence, options to either try to gain competitive advantage, through investment, may conflict with building long-term relationships. Payoffs in period one are computed by subtracting a participants' investments from their profits. The decision process due to the sequential nature of the game is as follows: The Stackelberg leader chooses a quantity in period one and notes it on the provided report card. The leader's choice is reported to the Stackelberg follower who enters the leaders quantity into their report card and spreadsheet. The leader's quantity then generates four quantities for the followers to choose from. After Stackelberg followers make their choices, quantities, profits, investments, period 2 costs, and payoffs become common knowledge in each duopoly. Spreadsheets then generated four choices for leaders in period two based on the results from period one and the sequential process starts over.

5 Experimental Results

Theory appears to be a poor predictor of actual behavior. Given the available four quantities in period 1 of the experiment, a Cournot quantity in period two can only exist if period one strategies consist of $(C|C)$ or $(A/R|R)$, i.e. (40|40) or (60|60), rendering the Cournot quantity relatively fragile to period 1 decision making. Nonetheless, the experiment showed that the Cournot quantity was the most frequently selected quantity, about 50% of the time (Figure 2). In fact, only one game was consistent with the theoretical prediction of absolute profit maximizing strategies of both leader and follower, while 39 games consisted of all Cournot play. All quantities other than the Cournot quantity, are selected infrequently – in period one alone it was selected 110 out of 200 times or 55%. This result strongly contradicts predicted behavior, suggesting that players behavior may be motivated by preferences such as inequality aversion. This behavior can be particularly well observed when comparing first and second mover choices to theorized predictions. Figure 3 shows large discrepancies between predicted and observed behavior. Using a Wilcoxon singed-rank test (two-tailed), we find that these differences are statistically significant ($p < 0.001$).

There are two particularly compelling reasons as to why participants in this experiment appear to be inequality averse. (1) First movers may fear sever punishment by second movers if first movers exploit their first mover advantage, which could potentially erode

Figure 2: Frequency of chosen quantities

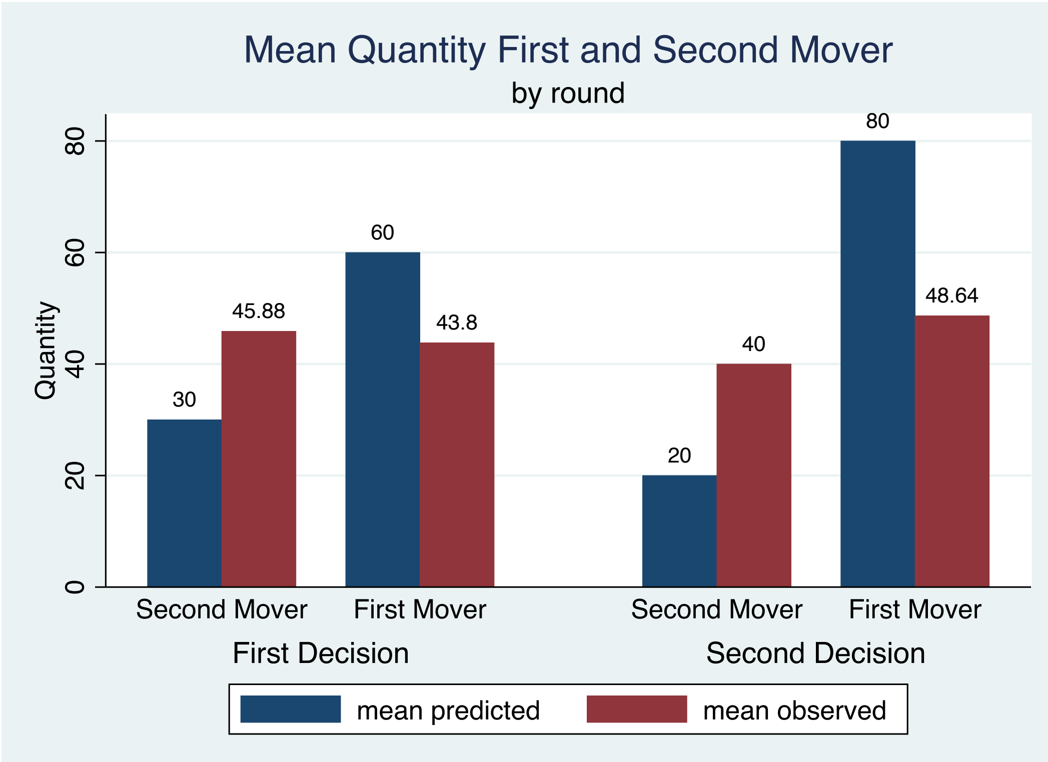


profits all together. Hence, there is room for spiteful behavior[2] if second movers decide to deviate from their dominant follower strategy and behave competitively – this first argument would make participants inequality averse by necessity and not by strictly by "preference." Participants faced the same competing decision maker in all ten games and both participants needed to consider how current choices may influence their future relationship. If leaders decided to play the Cournot quantity they may have done so out of fear of punishment by the followers. Similarly, Stackelberg followers may reciprocate with Cournot quantities to build and maintain an equitable relationship in future games. This behavior might suggest that individuals coordinate their behavior over time and may have stronger preferences to sustain equitable market share over competitive and potentially hostile market conditions in which all potential profits disappear. (2) Participants may actually be inequality averse. Regardless of the underlying preferences, (1) and/or (2), these results suggest that dynamic sequential choice games produce are less competitive than predicted by theory. A behavior that has previously been observed by Huck et al. (2002) Huck et al. (2002) in static one-shot games.

The differences between predicted and observed behavior are stark. We suggested earlier

[2]The usual definition of spite would require the Stackelberg leader being hurt more than the spiteful follower. However, due to the sequential nature of the game, this is an impossibility as followers maximum spite lies in relative profit maximizing quantities leading to zero profits for both players. Nonetheless, the loss in potential payoff is greater for the leader than for follower. Moreover, it is difficult to pinpoint spite as a pure motive as relative profit maximizing quantities may be used to punish leaders to change future outcomes instead of only receiving joy from beating the opponent.

Figure 3: Frequency of chosen quantities



that these differences are due to inequality aversion, which may be the result of a credible punishment threat by second movers. Theory predicted one sub-game perfect Nash equilibrium in pure strategies consisting of only absolute profit maximizing behavior, which created large payoff differences in period one but even larger payoff inequality in period 2. Thus, first movers had to decide if they wanted to (ab)use their first mover advantage in an attempt to widen the payoff gap in period two. The decision situation was different for the followers, as they were able to punish leaders for playing their dominant strategy and counter strike to eliminate all profits and pressure leaders to change their strategies in the following period and games. A simple OLS model sheds light on these behaviors. Table 1 shows that first movers significantly ($p < 0.001$) increase quantity in the second period, which indicates that they may be less fearful of second mover punishment in period two. Apparently, this behavior is justified as Table 2 shows that second movers significantly ($p < 0.001$) decrease quantity in period two. Perhaps these regression results suggest that inequality aversion is a necessary behavior to maintain a relationship over time rather than pure preferences for equal pay. Over time, as shown in Table 1, first movers significantly ($p < 0.001$) reduce quantity in an effort to maintain a relationship that is characterized by equality in payoffs (second movers also reduce their quantity over time but this reduction is not significant, which makes sense as they use quantity to punish first mover advantages).

Table 1: First mover behavior between periods and over time

Quantity	Coefficient	Standard Error	P-Value
Period	4.84	1.274	0.000
Game	-1.062	0.221	0.000
Constant	44.803	2.355	0.000

Note: OLS regression model; n=200, R^2=0.16.

Table 2: Second mover behavior between periods and over time

Quantity	Coefficient	Standard Error	P-Value
Period	-5.88	1.277	0.000
Game	-0.314	0.222	0.179
Constant	53.49	2.361	0.000

Note: OLS regression model; n=200, R^2=0.11.

For example, Figure 4 depicts participants 5 (first mover) and 15 (second mover) in period 1. The two players were able to established coordination of quantities over time. Player 5 notes that in the beginning her behavior was characterized by profit maximization which changed towards the middle of the game to what she referred to as stable profits (stable in the sense of equal payoff distribution at the Cournot quantity). Player 15 writes that he was interested in signaling cooperation and to "educate" (punish or suggest a better quantity) the opponent if he did not like her choice. Starting in period 6 both players successfully coordinated their strategies at the Cournot quantity. Period two is the last period in each game and thus punishment may be less credible. So first movers may look for their dominant strategy in period two more so than in period one. This effect may be weakened by the fixed pairing, i.e. punishment may happen to change the outcome in the following games – this behavior is depicted in Figure 5 where participants 8 (first mover) and 18 (second mover) converge to Cournot quantities in period 2 after game 5.

Theory predicts that first movers earn an equilibrium payoff of 4550 and followers earn 1300. However, the average equilibrium payoff for first and second movers was 2675.62 and 2506.85, respectively, which is below the Cournot prediction of 3200 and substantially different from the theoretical prediction. Given participants quantity choices, we found that first and second mover earning were quite similar. Figure 4 shows the large differences between

Figure 4: Behavior of participants 5 and 15 in period 1

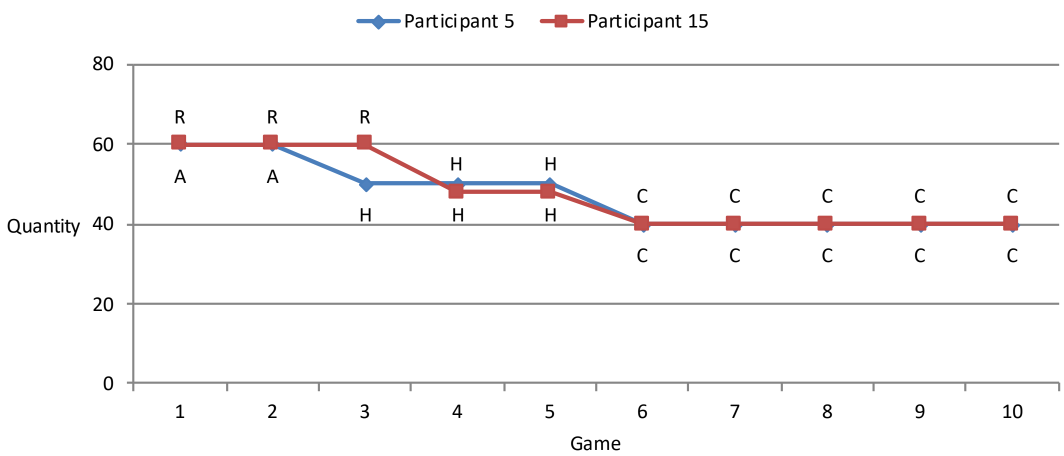
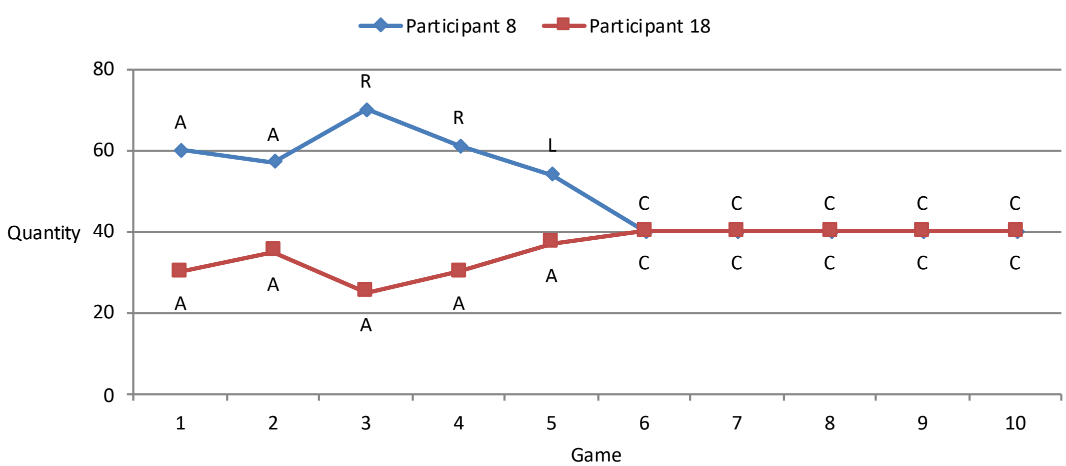
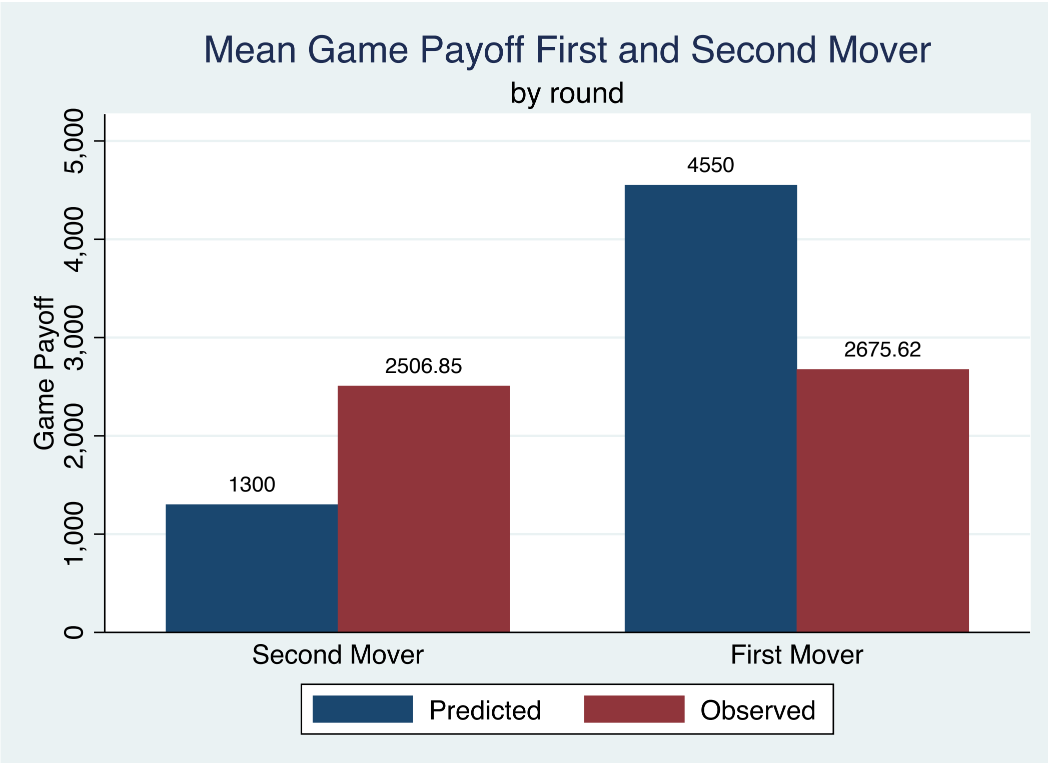


Figure 5: Behavior of participants 8 and 18 in period 2



predicted and observed payoffs. A Wilcoxon singed-rank test (two-tailed) showed that these differences are statistically significant ($p < 0.001$). However, we find no significant payoff difference between first and second movers ($p > 0.1$), indicting that participants generally achieved equality in payoffs. Participants 10 and 20, for example, achieved a perfect Cournot run (Figure 7) and earned the largest payoff in the experiment. Participants 7 and 17, on the other hand, consisted of the fewest Cournot plays and achieved the lowest payoff for both first and second mover (figure 8). Investment into cost-saving technologies to gain a stronger market position, i.e. lower marginal cost, which may have motivated players towards relative profit maximizing strategies, only occurred 35 out of 200 times or 17.5% and only in 8 of the 35 times was the investment achieved by first movers. Why did second movers outperform first movers to lower marginal cost in period two? There are at least two potential answers.

Figure 6: Predicted and observed payoffs for first and second movers



The first one is that in 92 first period choices first movers were either unable to achieve lower marginal cost, due to punishment by second movers, or they did not attempt to achieve lower marginal cost out of preferences for equity or out of fear over punishment by second movers. The second is that second movers achieved a cost advantage 27 times, suggesting that, perhaps, they harshly punished first movers for choosing any quantity other than the Cournot quantity.

For example, Figure 9 depicts participants 6 (first mover) and 16 (second mover) in period 1. Although the first mover does not fully use his first mover advantage, the second mover replies by selecting relative profit maximizing strategies in the first 3 games and continuously selects quantities at least as high as the leader. In this particular example the second mover actually outperformed the first mover in terms of payoff at the end of the experiment. Overall, 3 second movers outperformed the first mover in terms of payoff.

Figure 7: Period payoffs for participants 10 and 20

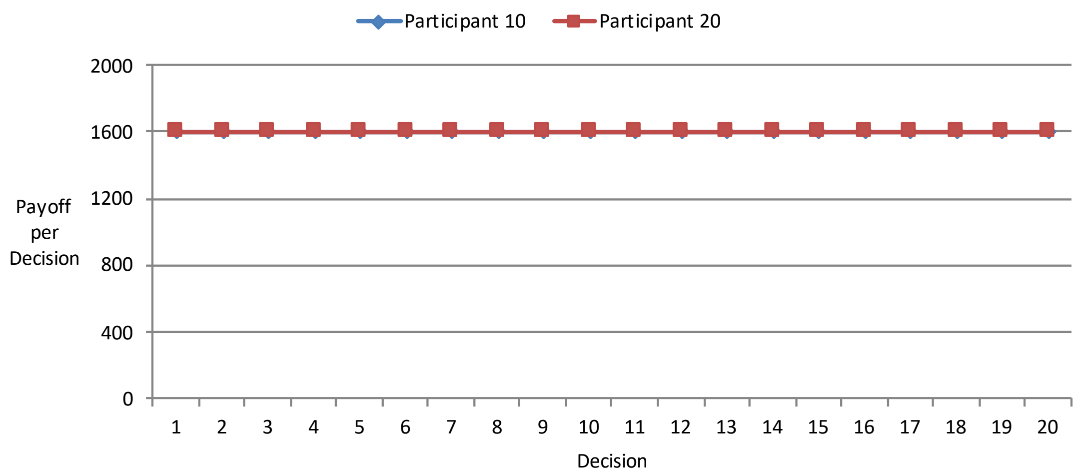
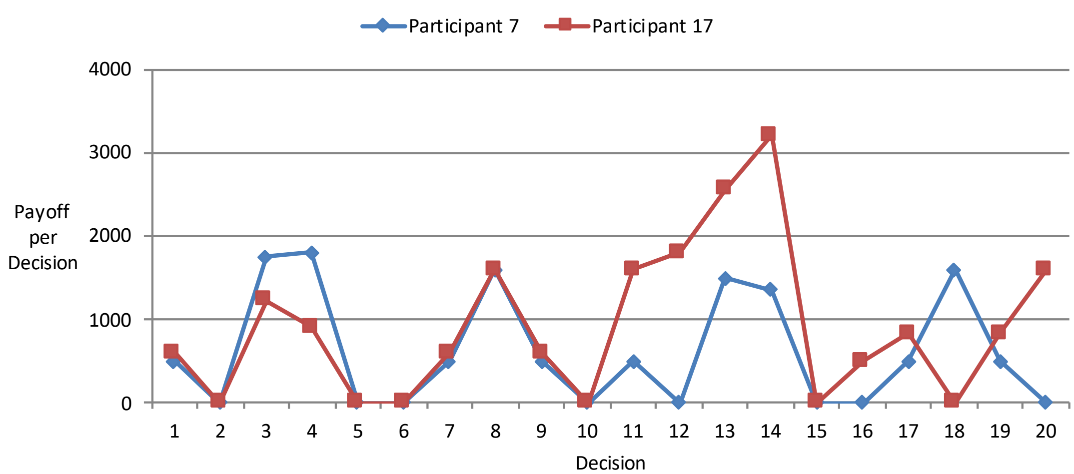


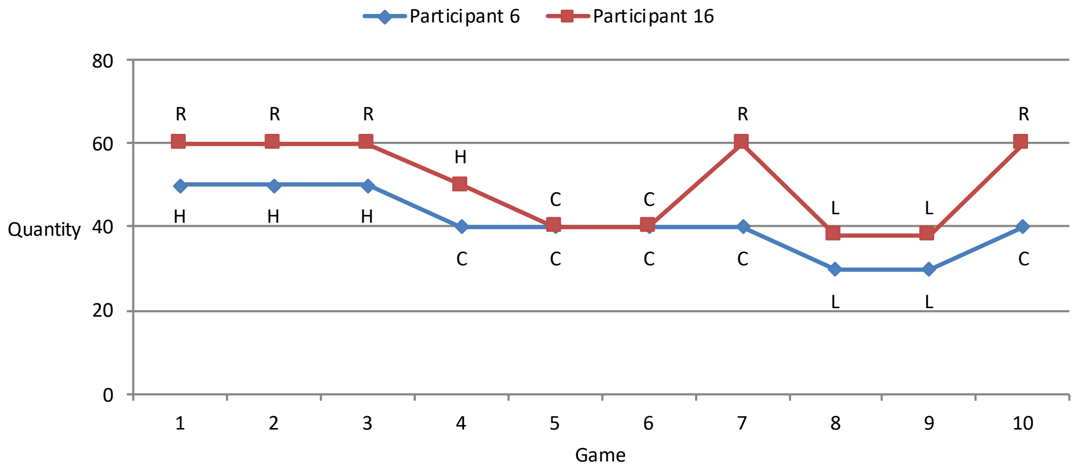
Figure 8: Period payoffs for participants 7 and 17



6 Summary and Concluding Remarks

This study introduces a two-player two-period sequential choice model, which is tested in controlled laboratory experiments. Observed behaviors were far from theorized predictions, i.e. Stackelberg leadership never emerged. Instead, participants coordinated around the Cournot quantity, suggesting that these experiments were predominantly characterized by inequality aversion rather than profit maximizing behaviors. Punishment by second movers was a credible threat and first movers adapted to this threat by choosing Cournot quantities, which signaled first movers' willingness to equitably share market profits and maintain relationships over time. Large payoff discrepancies between first and second movers, as predicted by theory, were not observed. No significant differences were found between first and second

Figure 9: Behavior of participants 6 and 16 in period 1



mover earnings. Overall, long-term relationships with an equal market split was observed and followers largely used relative profit maximizing strategies to punish and not to gain competitive advantage.

Future research should investigate if the behaviors reported on in this study are robust to changing opponents as opposed to playing the same opponent over the entire length of the game. It may also be of interest to examine how behavior responds to making investments a separate choice variable. This, however, would make the game more complex, given the potentially infinitely large number of strategies.

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